Docket No.: M4065.0316/P316-A
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Gurtej Sandhu, et al.

Examiner: Alexander G. Ghyka

Application No.: 10/684,431

Group Art Unit: 2812

Filed: October 15, 2003

For: SEMICONDUCTOR DEVICES USING ANTI-REFLECTIVE COATINGS

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

DECLARATION OF ZHIPING YIN UNDER 37 CFR 1.131

Dear Sir:

I, Zhiping Yin, declare and state as follows:

1. I reside at 1462 East Regata Street, Boise, Idaho 83706.

2. The above-identified application ("the '431 application") is a divisional of U.S. Patent Application No.: 09/252,448 ("the '448 parent application"), filed on February 18, 1999, which issued as U.S. Patent No.: 6,713,234 on March 30, 2004.

3. I am one of the joint inventors of the '448 parent application, filed on February 18, 1999, as evidenced by the attached the executed Declaration document, filed with the United States Patent and Trademark Office on February 18, 1999 (Exhibit A).

4. I have reviewed and understand the '431 application, including the currently pending claims and amendments (the "Claimed Invention").

5. I, together with Gurtej S. Sandhu, jointly conceived the invention covered by the Claimed Invention prior to January 27, 1999, as evidenced by Exhibit B, which is a Micron Invention Disclosure document. The actual date on this submission has been blacked out, as has any description not relevant to the conception of the Claimed Invention; however, the date is prior to January 27, 1999. Micron Technology Inc. is the assignee of the present application.

6. The law firm of Fish & Richardson, P.C. ("Fish & Richardson") was assigned to write this application, as evidenced by attached Exhibit C, which is a copy of a letter from Micron to Fish & Richardson, forwarding a final draft of the patent application, identified by Micron reference number 97-0897, for my review. The actual date on this submission has been blanked out, as has any description not relevant to the conception of the Claimed Invention; however, the date is prior to January 27, 1999.

7. Following the Exhibit C correspondence and additional review of the application, my co-inventor and I sent additional comments to the legal department of Micron. Micron then forwarded our further comments to Fish & Richardson, as evidenced by Exhibit D, which is a letter forwarding a marked up draft application to Fish & Richardson. The actual date on this submission has been blanked out, as has any

description not relevant to the conception of the Claimed Invention; however, the date is prior to January 27, 1999.

8. Fish & Richardson received the application and a revised draft of the patent application was forwarded in a letter to Micron, Exhibit E. The actual date on this submission has been blanked out, as has any description not relevant to the conception of the Claimed Invention; however, the date is prior to January 27, 1999.

9. The final patent application covering the Claimed Invention was reviewed and executed by myself and my co-inventor on February 15, 1999, as evidenced by the Declaration attached as Exhibit A. The final draft, Assignment and Declaration were executed and forwarded by Micron to Fish & Richardson with a letter dated February 16, 1999, Exhibit F. The present application was filed in the United States Patent and Trademark Office on February 18, 1999. The preparation of the presentation of the present application covering the Claimed Invention was diligently pursued from prior to the reference date of January 27, 1999 to the date of filing (February 18, 1999) of the '448 parent application, from which the '431 application is a divisional of.

All statements made herein of my own knowledge are true and all statements made on information and belief are believed to be true; and these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the above-identified patent.

Date: 10/19/04 By: Zhiping Yin

Zhiping Yin

COMBINED DECLARATION AND POWER OF ATTORNEY

As a below-named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled FABRICATION OF SEMICONDUCTOR DEVICES USING ANTI-REFLECTIVE COATINGS, the specification of which

- ■ is attached hereto.
- ☐ was filed on _____ as Application Serial No. _____ and was amended on _____.
- ☐ was described and claimed in PCT International Application No. _____ filed on _____ and as amended under PCT Article 19 on _____.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose all information I know to be material to patentability in accordance with Title 37, Code of Federal Regulations, §1.56.

I hereby appoint the following attorneys and/or agents to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith: Michael L. Lynch, Reg. No. 30,871; Lia M. Pappas, Reg. No. 34,095; W. Eric Webostad, Reg. No. 35,406; Charles B. Brantley II, Reg. No. 38,086; Samuel Borodach, Reg. No. 38,388; Victor Siber, Reg. No. 27149; Stephan J. Filipek, Reg. No. 33,384; John B. Pegram, Reg. No. 25,198; William J. Hone, Reg. No. 26,739; Frederick H. Rabin, Reg. No. 24,488; Richard P. Ferrara, Reg. No. 30,632; Gabriel P. Kralik, Reg. No. 34,855; Andrew T. D'Amico, Reg. No. 33,375; Andrew N. Parfomak, Reg. No. 32,431.

Address all telephone calls to Samuel Borodach at telephone number 212/765-5070.

Address all correspondence to Victor Siber, Fish & Richardson P.C., 45 Rockefeller Plaza, New York, NY 10111.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patents issued thereon.

Full Name of Inventor: Gurtej S. Sandhu

Inventor's Signature: Gurtej Singh Sandhu Date: 2/15/99

Residence Address: Boise, Idaho

Citizen of: United Kingdom

Post Office Address: 2964 East Parkriver Drive, Boise Idaho 83706

COMBINED DECLARATION AND POWER OF ATTORNEY CONTINUED

Full Name of Inventor: Zhiping Yin

Inventor's Signature: Zhiping Yin Date: 2/15/99

Residence Address: Boise, Idaho

Citizen of: Peoples Republic of China

Post Office Address: 1462 East Regatta Street, Boise Idaho 83706

42536.N11

ARPA project,
ase check below:

- Advanced SRAM
- BST
- FED
- FE RAM
- NCAICM

INVENTION DISCLOSURE

97-897

RECEIVED

[redacted]

INVENTOR(S): Gurtej S Sandhu
Zhiping Yin

DESCRIPTION

2.1 Title of invention:

A METHOD TO INTEGRATE DARC FILMS ON TRANSPARENT UNDERLAYERS IN A OCESS FLOW.

2.2 Brief description:

Dielectric anti reflective coatings (DARC) have recently been applied improve photo performance for I line and UV lithography. The standard plicaton of DARC film involves a highly reflective underlayers which cause flective notching in photo resist. However, for applications such as 40 or level, DARC is deposited on BPSG films which are transparent. The flective notching is caused by underlying reflective structures of different apes and at different depths which makes it impossible to optimize nventional DARC flow for low reflective notching.

A method to use DARC films in such applications and minimize reflective tching is prosposed here. The method consists of depositing DARC layer below BG3. This DARC layer with high n and k value is optimized to give maximum flectivity and absorption and therefore, the underneath structure effects on oto will be minimized. For the case when the surface of the BPSG may not be anar, an additional DARC layer on top of the BPSG is used to act as a nventional DARC layer as shown in figure 1. Since the substrate reflectivity uniform and predictable (from DARC layer 1), the DARC2 can be optimized for nimum reflective notching by using standard simulation procedures. In neral, the rule of the thumb is to maximize n1 and k1 in order to maximize e reflectivity from the surface of DARC1 and minimize the transmitted light rough this layer which can then get reflected from underlying structures and e back up through DARC1. In the case of planzarized structures, the flectivity of the substrate need not be minimized (just adjust the photo dose needed) as long as reflective surface is planar and uniform as shown in gure 2. Only one DARC layer can be used to make sure that the underlying ructures do not affect photo performance in this case. The n and k should ain be very high in this case also.

2.3 Also attach a complete description, including drawings or sketches and articles relevant to the invention. Legible photocopies of laboratory notebooks are acceptable.

In general, for minimum notching -

$$n_1 \gg n_3, n_4$$

$k_1 \rightarrow$ as high as possible

Optimize n_2, k_2, t_2 by conventional means

Figure 1

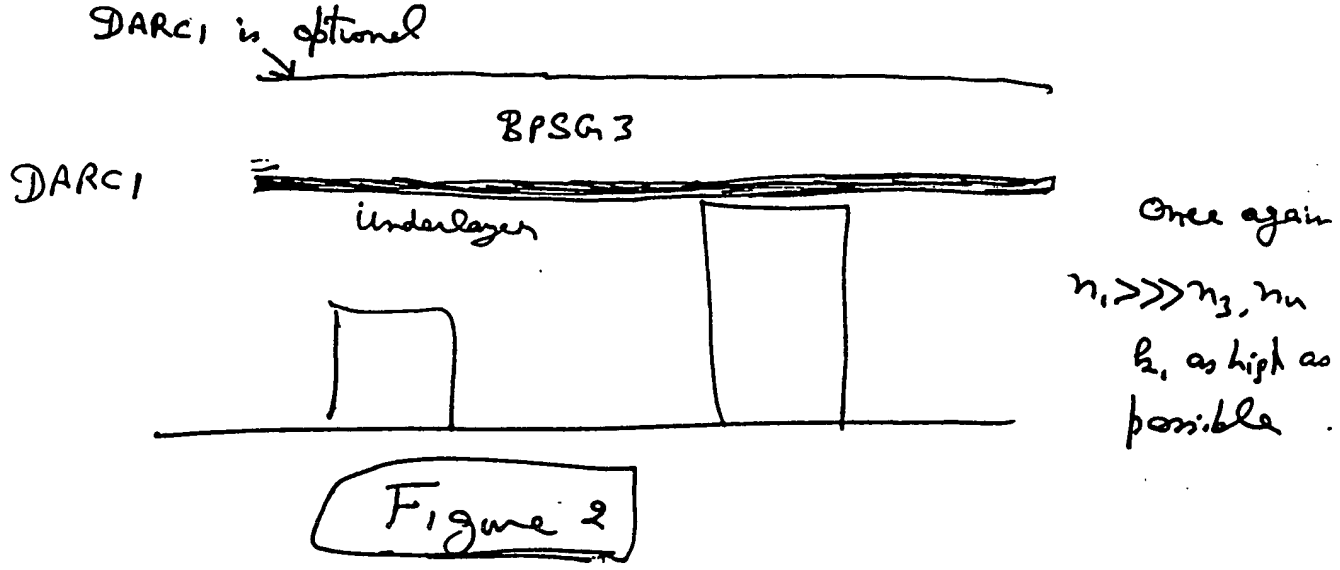

Figure 2

3. INFORMATION CONCERNI CONCEPTION OF INVENTION

3.1 CONCEPTION AND DOCUMENTATION OF THE INVENTION

a. Identify the date when you first conceived the invention. (If not sure, give the earliest date of which you are sure.)

[redacted]

b. To whom was the idea first described and on what date? (Other than a co-inventor.)

c. Identify the date of the first tangible record such as computer simulation, tape out, drawing or written description. Please specify type and location.

3.2 CONCEPTION OF THE IN. .TION

a. Please ide)ify related invention dis)osures, patents or other publications describing similar ideas, and other companies working in the same field. Attach copies, if available.

b. What is the closest technology, of which you are aware?

Standard DARC or BARC technology.

c. Identify the advantages of this invention over previous technology.

Makes it possible to use DARC layers on top of transparent underlayers.

3.3 IMPORTANT DATES

a. Has the invention been disclosed outside the company? _____ If yes, to whom, when, and in what form?

b. Have any articles describing your invention been published? _____ If yes, list author(s), title of article, publication and date.

c. Have any engineering samples been given out? _____ If yes, to whom and on what date?

d. Has any product using the invention been sold or offered for sale? _____ If yes, to whom and on what date?

3.4 DISPOSITION OF THE INVENTION

a. When will (or did) Micron begin use of the invention experimentally?

b. When will (or did) Micron begin production of this invention?

3.5 MISCELLANEOUS IN ORMATION

a. Was the in htion developed during a joint development agreement or other contract with an outside company? _____

b. Please list developmental work outside of the company (including Government proposal or contract).

4. INVENTORS:

Name: Gurtej S Sandhu

Micron Phone: 84238 Micron Mail Stop: _____

Company Name (VERY IMPORTANT): Dept. Name: _____
___ Micron Technology, Inc. Dept. #: _____
___ Micron Electronics, Inc.
___ Micron Quantum Devices
___ Micron Display Technology, Inc.
___ Micron Communications, Inc.
___ Other_____

Home Address: _____

_____

Citizenship: US

Supervisor: _____

Signature: Gurtej Sandhu Date: [redacted]

Name: Zhiping Yin

Micron Phone: _____ Micron Mail Stop: _____

Company Name (VERY IMPORTANT): Dept. Name: _____
___ Micron Technology, Inc. Dept. #: _____
___ Micron Electronics, Inc.
___ Micron Quantum Devices
___ Micron Display Technology, Inc.
___ Micron Communications, Inc.
___ Other_____

Home Address: _____

_____

Citizenship: P.R. China

Supervisor: _____

Signature: Zhiping Yin Date: [redacted]

Name: _____

Micron Phone: _____ Micron Mail Stop: _____

Company Name (VERY IMPORTANT): Dept. Name: _____
___ Micron Technology, Inc. Dept. #: _____
___ Micron Electronics, Inc.
___ Micron Quantum Devices
___ Micron Display Technology, Inc.
___ Micron Communications, Inc.
___ Other_____

Home Address: _____

_____

Citizenship: _____

Supervisor: _____

Signature: _____ Date: _____

-- If more than three inventors use additional form(s) available in the Legal Department, 3rd floor, Administration building. --

5. WITNESS

If there is only one inventor, a witness should sign and date this disclosure. A witness in this case is a non-inventor who understands the nature of the invention.

_____ _____
(Signature of Witness) (Date)

Note: If you have any questions or wish assistance completing this form, please call the Legal/Patent Department, ext. 4527.

FISH & RICHARDSON P.C.

45 Rockefeller Plaza
Suite 2800
New York, New York
10111

Telephone
212 765-5070

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212 258-2291

Web Site
www.fr.com

[redacted]

By Federal Express

Micron Technology, Inc.
c/o Ms. Susan Jerome
8000 S. Federal Way
P.O. Box 6
Boise, Idaho 83707-0006

Re: Your Ref. 97-0897
New Patent Application
DARC Films Below Transparent Layer
Inventors: Gurtej Sandhu; Zhiping Yin
Our File 07653/019001

Dear Ms. Jerome:

Thank you for your letter of [redacted] Please find enclosed the following documents:

(1) Final draft of the patent specification for the matter identified above;

(2) Combined Declaration and Power of Attorney; and

(3) Assignment.

Kindly have the inventors review the draft and, if everything is in order, sign and date items (2) and (3). Please note that item (3) should be notarized. The executed documents should then be returned to me for filing with the U.S. Patent and Trademark Office.

Very truly yours,

Samuel Borodach
Enclosures
44427.N11

MICRON
TECHNOLOGY, INC.

RECEIVED

[redacted]

[redacted]

FISH & RICHARDSON, P.C.

Samuel Borodach
Fish & Richardson
45 Rockefeller Plaza
Suite 2800
New York, NY 10111

Re: Micron Ref. No. 97-0897
Your Ref. No. 07653/019001
FABRICATION OF SEMICONDUCTOR DEVICES USING ANTI-REFLECTIVE COATINGS

Dear Samuel:

Enclosed please find a revised draft application, for the above case, I am forwarding to you on behalf of the inventors. Please incorporate these comments into a new draft for their review.

If you have any questions, please do not hesitate to call.

Sincerely,

Susan Jerome

Susan Jerome
Patent Assistant

Phone: (208) 368-4508
Fax: (208) 368-5606

Target Filing Date [redacted]
* No Docketing Required
Reviewed By Docketing Assistant
Initials: JLJ
Reviewed by Docketing Manager
Initials:

FISH & RICHARDSON P.C.

45 Rockefeller Plaza
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Web Site
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[redacted]

By Federal Express

Micron Technology, Inc.
c/o Ms. Susan Jerome
8000 S. Federal Way
P.O. Box 6
Boise, Idaho 83707-0006

Re: Your Ref. 97-0897
New Patent Application
DARC Films Below Transparent Layer
Inventors: Gurtej Sandhu; Zhiping Yin
Our File 07653/019001

Dear Ms. Jerome:

Thank you for your letter of [redacted]

Please find enclosed four (4) copies of a revised draft for the patent specification identified.

Very truly yours,

Samuel Borodach

Enclosure

46901.N11

MICRON®
TECHNOLOGY, INC.

RECEIVED
FEB 17 1999
FISH & RICHARDSON, P.C.

February 16, 1999

Samuel Borodach
Fish & Richardson
45 Rockefeller Plaza
Suite 2800
New York, NY 10111

Re: Micron Ref. No. 97-0897
Your Ref. No. 07653/019001
DARC FILS BELOW TRANSPARENT LAYER

Dear Samuel:

Enclosed please find the final draft application, for the above case, accompanied by the Assignment and Declaration that have been executed by the inventors.

I believe this case should now be ready for filing with the Patent Office.

If you have any questions, or I may be of assistance, please do not hesitate to call.

Sincerely,

Susan Jerome
Patent Assistant

Phone: (208) 368-4508
Fax: (208) 368-5606

APPLICATION

FOR

UNITED STATES LETTERS PATENT

TITLE: **FABRICATION OF SEMICONDUCTOR DEVICES USING ANTI-REFLECTIVE COATINGS**

APPLICANT: **GURTEJ S. SANDHU; ZHIPING YIN**

"EXPRESS MAIL" Mailing Label Number EF647285046U

Date of Deposit February 18, 1999

I hereby certify under 37 CFR 1.10 that this correspondence is being deposited with the United States Postal Service as "Express Mail Post Office To Addressee" with sufficient postage on the date indicated above and is addressed to the Assistant Commissioner for Patents, Washington, D.C. 20231.

Francisco Robles

Francisco Robles

FABRICATION OF SEMICONDUCTOR DEVICES USING ANTI-REFLECTIVE COATINGS

Background

The present invention relates generally to the manufacture of semiconductor devices and, in particular, to methods for fabricating such devices using anti-reflective layers, as well as devices including anti-reflective coatings.

The fabrication of integrated circuits requires the precise positioning of a number of regions in a semiconductor wafer, followed by one or more interconnection patterns. The regions include a variety of implants and diffusions, cuts for gates and metallizations, and windows in protective cover layers through which connections can be made to bonding pads. A sequence of steps is required for each such region.

Photolithographic techniques, for example, can be used in the performance of some or all of the foregoing operations. Typically, for example, the surface of a wafer to be processed is pre-coated with a photoresist. The photoresist then is exposed to a light source with a suitably patterned mask positioned over the wafer. The exposed resist pattern is used, for example, to open windows in a protective underlying layer to define semiconductor regions or to delineate an interconnection pattern.

To improve the degree of integration and to obtain high density devices, performing photolithographic operations at shorter wavelengths is desirable. Currently, i-line techniques with a wavelength of about 365 nanometers (nm), KrF excimer laser techniques with a wavelength of about 248 nm, and KnF excimer laser techniques with a wavelength of about 193 nm are used. However, at those

wavelengths, optical reflections at the interfaces of previously-formed layers on the semiconductor wafer can cause notching of the photoresist.

FIG. 1 illustrates the general nature of the problem. A semiconductor wafer 10 includes one or more previously-formed layers 12 covered by a thick layer of boro-phospho-silicate glass (BPSG) 14. The BPSG layer 14 serves as a protective layer for the underlying layers 12 and also provides a more planar surface. A photoresist film 16 is coated over the BPSG layer 14, and a mask 18 is positioned over the photoresist prior to exposure of the photoresist to an appropriate source of radiation 20. The mask 18 can be used to define, for example, contact holes for one of the previously-formed layers 12.

Ideally, when the photoresist film 16 is exposed to the radiation 20, the mask 18 precisely defines the dimensions of the exposed regions of the photoresist film. However, the BPSG layer 14 is transparent to the wavelengths typically used in photolithography, including 248 nm and 365 nm. Thus, a significant amount of the radiation 20 that passes through the mask 18 travels through the BPSG layer 14 and is reflected at the interface between the BPSG layer and one or more of the previously-formed underlying layers 12. Some of the reflected radiation (indicated by arrow 22) contributes to exposure of the photoresist film 16.

In some situations, a dielectric anti-reflective coating is provided above the BPSG layer to reduce reflections from the underlying layers. However, if the structures in the previously-formed underlying layers 12 have varying dimensions or varying shapes and the level of reflected light is relatively high, the reflected light 22 will expose the photoresist film 16 non-uniformly leading to the formation of notching.

Summary

In general, techniques are disclosed for fabricating a device using a photolithographic process. The techniques are particularly advantageous for transferring an optical pattern by photolithography to one or more layers which are transparent to the wavelength(s) at which the photolithography is performed.

According to one aspect, a method includes providing a first anti-reflective coating over a surface of a substrate. As used herein, the term "substrate" refers to one or more semiconductor layers or structures which may include active or operable portions of semiconductor devices. Various films or other materials may be present on the semiconductor layers or structures. A layer which is transparent to a wavelength of light used during the photolithographic process is provided over the first anti-reflective coating, and a photosensitive material is provided above the transparent layer. The photosensitive material is exposed to a source of radiation including the wavelength of light. Preferably, the first anti-reflective coating extends beneath substantially the entire transparent layer.

According to another aspect, a semiconductor device includes a layer that is transparent to light having a wavelength, for example, of approximately 193 nm, 248 nm or 365 nm. A first anti-reflective coating extends substantially entirely beneath the transparent layer.

One advantage of providing an anti-reflective coating beneath the transparent layer is that the anti-reflective coating can help reduce notching of the photosensitive material that may occur during the photolithographic process.

In general, the complex refractive index of the first anti-reflective coating can be selected to maximize (or increase) the absorption at the first anti-reflective coating to minimize (or reduce) the amount of light transmitted through the first anti-reflective coating and reflected back from the underlying structures. Therefore, the effects of the non-uniform structures in the layers below the first anti-reflective coating can be reduced or eliminated. That, in turn reduces the amount of light that is reflected back toward the photosensitive material and, therefore, further reduces notching.

Various implementations include one or more of the following features. The transparent layer can include a material such as BPSG, PSG and TEOS. Other materials, including various oxides and nitrides, also can be used as the transparent layer. Depending on the properties of the photosensitive material, it can be exposed to radiation at various wavelengths including approximately 193 nm, 248 nm or 365 nm. Portions of the photosensitive material selectively can be exposed to the radiation.

The first anti-reflective coating can include various materials, including a material comprising silicon and nitrogen; silicon and oxygen; or silicon, oxygen and nitrogen. Other materials, such as organic polymers, also can be used as the first anti-reflective coating.

According to another aspect, in addition to the first anti-reflective coating, a second anti-reflective coating can be provided above the transparent layer. The photosensitive material then can be provided over the second anti-reflective coating. Providing the second anti-reflective coating between the photosensitive material and the transparent layer can further help reduce the effects of

light that is reflected from the interface of the first anti-reflective coating and the transparent layer.

Other features and advantages will be readily apparent from the following description, the accompanying drawings, and the claims.

Brief Description of the Drawings

FIG. 1 is a partial cross-section of a semiconductor wafer during performance of a photolithographic process.

FIG. 2 illustrates a cross-section of an exemplary, partially-fabricated semiconductor device.

FIG. 3 illustrates a cross-section of the device of FIG. 2 during performance of a photolithographic process according to the invention.

FIG. 4 illustrates a cross-section of the device of FIG. 3 following formation of a contact hole.

FIG. 5 illustrates a cross-section of a device having multiple layers to which a photolithographic pattern is to be transferred and which are transparent to the light used during the photolithographic process.

FIG. 6 illustrates a cross-section of a device during performance of a photolithographic process according to another embodiment of the invention.

Detailed Description

As explained in greater detail below, a technique is described for transferring an optical pattern by photolithography to one or more layers which are transparent to the wavelength(s) at which the photolithography is performed. The technique is described with respect to the formation of a contact hole through a BPSG layer. However, the technique is generally applicable to the formation of various features in integrated devices involving the

transfer of a pattern by photolithography to other transparent layers as well. Such layers include, for example, phospo silicate glass (PSG), tetra-ethyl-ortho-silicate (TEOS), undoped oxides, among others.

As shown in FIG. 2, an exemplary partially-fabricated semiconductor device includes an active region 30 formed on a semiconductor wafer 32 and surrounded by an isolation oxide film 34. A gate electrode 36 is formed in the active region 30 with a gate oxide film 38 disposed between the electrode and the active region. The gate electrode 36 includes a first polycrystalline silicon (poly-Si) film 40 and a first refractory metal silicide film 42. The gate electrode 36 has its top portion covered with a silicon oxide film 44 and its sidewalls covered with an insulation film 46.

Impurity diffusion layers 48 form source and drain regions at the upper surface of the wafer 32 at either side of the gate electrode to provide a metal-oxide-semiconductor (MOS) field effect transistor structure. A silicon oxide layer 56 is provided over the surface of the substrate.

A first interconnection layer 50, including a second poly-Si layer 52 and a second refractory metal silicide layer 54, is formed on one of the impurity diffusion layers 48. As shown in FIG. 2, a silicon oxide film 58 is formed over the entire upper surface of the substrate.

Techniques for forming the foregoing layers are well-known and, therefore, are not described in further detail.

Prior to forming a protective BPSG layer, a first dielectric anti-reflective coating (ARC) 60 is formed over substantially the entire upper surface of the substrate (FIG. 3). In one implementation, the first dielectric ARC 60 has a thickness in the range of approximately 200-500

angstroms (Å), although in general, the thickness will vary depending on the particular application and can be greater than 500 Å or less than 200 Å.

Next, a BPSG layer 62 is deposited on the first dielectric ARC 60, for example, by vapor deposition. The BPSG layer 62 can be heated at a temperature of approximately 850 celsius (°C) to form an interlayer insulation film having a relatively flat surface. The thickness of the BPSG layer 62 is typically much greater than the thickness of the first dielectric ARC 60 and may be as great as 20,000 Å. Preferably, the first ARC 60 extends substantially beneath the entire BPSG layer 62.

A second dielectric ARC 64 is formed over substantially the entire upper surface of the BPSG layer 62. The second dielectric ARC 64 also can include, for example, a silicon oxide (Si_xO_y:H) film, a silicon nitride film (Si_xN_y:H) or a silicon oxy-nitride ($Si_xO_yN_z$:H) film. Other materials also can used for the second dielectric ARC 64. In one implementation, the second dielectric ARC 64 has a thickness in the range of approximately several hundred angstroms (Å), although in general, the thickness will vary depending on the particular application and can be greater or less.

A photosensitive film, such as a photoresist 66, is deposited over the second dielectric ARC 64, and a mask 68 is positioned over the photoresist prior to exposure of the photoresist to an appropriate source of radiation 70. Depending on the properties of the photoresist, the radiation which exposes the photoresist can include one or more different wavelengths. Exemplary sources of radiation include those used in i-line techniques with a wavelength of about 365 nanometers (nm), KrF excimer laser techniques with a wavelength of about 248 nm, and KnF excimer laser

techniques with a wavelength of about 193 nm. In the illustrated example of FIG. 3, the mask 68 is used to define contact holes for one of the previously-formed layers.

One advantage of providing the dielectric ARC 60 immediately below the BPSG layer 62 is that the ARC 60 can reduce the amount of notching that may result during the photolithographic process for defining the contact holes. In general, the complex refractive index of the first ARC 60 can be selected to maximize the absorption at the first anti-reflective coating to minimize amount of transmitted light through the first anti-reflective coating back from the underlying structures. Therefore, the effects of the non-uniform structures in the layers below the first ARC can be reduced or eliminated. That, in turn reduces the amount of light that can be reflected back toward the photo-sensitive material and, therefore, further reduces notching.

The complex refractive index of a material includes a real part n, known as the refractive index and defining the velocity of light in the material, and an imaginary part k which corresponds to the material's light absorption coefficient. In the discussion that follows, the real and imaginary parts (n, k) of the complex refractive index for the various layers will be referred to as follows:

Layer	n	k
Underlayer	n_1	k_1
First ARC (60)	n_2	k_2
BPSG (62)	n_3	k_3
Second ARC (64)	n_4	k_4

The reflectance and transmittance at the interface of the BPSG layer 62 and the first dielectric ARC 60 are determined by n_2, k_2, n_3 and k_3. To increase the absorption in the first dielectric ARC 60, k_2 should be relatively

high, for example, at least as high as 1.0 and preferably as high as 1.5.

The first dielectric ARC 60 can include, for example, a silicon oxide (Si_xO_y:H) film, a silicon nitride (Si_xN_z:H) film or a silicon oxy-nitride ($Si_xO_yN_z$:H) film. Other materials, including titanium nitride and organic compounds such as polymers, also can used for the first dielectric ARC 60. In one implementation, a $Si_xO_yN_z$:H layer can be formed as the ARC 60 using a plasma-enhanced vapor deposition technique. A film including a mixture of silicon (Si), oxygen (O), nitrogen (N) and hydrogen (H) atoms can be formed by exciting a plasma in a gas mixture of silane and nitrogen oxide (N_2O) diluted by helium (He). For example, to obtain a $Si_xO_yN_z$:H layer with a value of n equal to about 2.13 and a value of k equal to about 1.23 for light having a wavelength of 248 nm, the flow rates of silane, N_2O and He can be approximately 80 sccm, 80 sccm and 2200 sccm, respectively. The $Si_xO_yN_z$:H layer is formed at a temperature of about 400 °C and a pressure of about 5.6 Torr. The RF power can be set to approximately 105 watts.

If the topography of the underlying structure below the first ARC 60 is not substantially planar, then light reflected from the interface of the first ARC and the BPSG layer 62 will tend to scatter in various directions non-uniformly. Providing the second ARC 64 between the photoresist layer 66 and the BPSG layer 62 can help reduce the effects that any such non-uniform light has on the photoresist.

The second ARC 64 also can include, for example, a Si_xO_y:H film, a Si_xN_z:H film or a $Si_xO_yN_z$:H film. Other materials, including titanium nitride and organic compounds such as polymers, also can be used for the second dielectric ARC 64. In general, the values of n_4 and k_4 for the second

ARC 64 should be selected to minimize or reduce the reflectivity at the interface between the photoresist layer 66 and the second ARC 64. Selecting a suitable material for the second ARC 64 can be determined using known simulated techniques. Generally, however, selection of the material for the second ARC 64 will depend on the BPSG layer 62 as well as on the first ARC 60. The layers below the first ARC 60 can be ignored due to the high absorption of the first ARC 60.

Once the photolithographic process is performed and the photoresist 66 is developed, the ARC 64, the BPSG layer 62, the ARC 60, the silicon oxide layers 56, 58 and the gate oxide film 38 are etched successively to form a contact hole 72 (FIG. 4). The remaining resist 66 then can be removed, and fabrication of the device, including the formation of metallization contacts, can be completed using conventional techniques. Upon completion of the device, the first anti-reflective coating 60 will extend beneath substantially the entire transparent layer 62.

In some cases, the layer which is transparent to the wavelength(s) of light may include multiple vertically stacked layers 62A, 62B (FIG. 5) rather than a single layer, where each of the multiple layers 62A, 62B is transparent to the wavelength(s) of light used during the photolithographic process.

In situations where the topography of the underlying structures below the first anti-reflective coating is substantially planar, the second anti-reflective coating need not be provided. As shown in FIG. 6, a semiconductor wafer 80, which may include one or more previously-formed layers or regions, has a substantially planar topography. An anti-reflective coating 82 is provided over the wafer 80. The composition of the anti-reflective coating 82 can be

similar to those discussed above with respect to the anti-reflective coating 60. In general, as previously discussed, the complex refractive index of the anti-reflective coating 82 should be selected to maximize the absorption at the anti-reflective coating to minimize the amount of transmitted light through the anti-reflective coating back from the underlying structures formed on the wafer 80. A BPSG or other protective layer 84 is provided over the anti-reflective coating 82. A photo-lithographic pattern then is formed by providing a photosensitive film 86, such as photoresist, over the protective layer 84 and exposing the photoresist to an appropriate source of radiation 90 with a mask 88 in place over the photoresist. Although the protective layer 84 is transparent to the radiation 90, any light reflected from the interface of the protective layer and the anti-reflective coating 82 will tend to be reflected substantially uniformly. Therefore, notching of the photoresist pattern 86 can be reduced or eliminated.

Although the foregoing techniques have been described with respect to a protective layer in a specific semiconductor device, an anti-reflective coating can be provided immediately below any layer to which a photo-lithographic pattern is to be transferred and which is transparent to the wavelength of light used during the photolithographic process.

Other implementations are within the scope of the following claims.

What is claimed is:

1. A method of fabricating a device using a photolithographic process, wherein a wavelength of light is used during the photolithographic process, the method comprising:

providing an anti-reflective coating over a surface of a substrate;

providing a layer which is transparent to the wavelength of light over the anti-reflective coating;

providing a photosensitive material above the layer that is transparent to the wavelength of light; and

exposing the photosensitive material to a source of radiation including the wavelength of light.

2. The method of claim 1 wherein the anti-reflective coating extends beneath substantially the entire transparent layer.

3. The method of claim 2 wherein providing an anti-reflective coating includes providing an anti-reflective coating with a complex refractive index which increases absorption of light passing through an interface of the transparent layer and the anti-reflective coating.

4. The method of claim 2 wherein exposing the photosensitive material to a source of radiation includes selectively exposing portions of the photosensitive material to the radiation.

5. The method of claim 4 further including:

developing the photosensitive material after exposure to the source of radiation; and

transferring a pattern defined by the remaining photosensitive material to at least one underlying layer.

6. The method of claim 2 wherein exposing the photosensitive material to a source of radiation includes exposing the photosensitive material to radiation having a wavelength of approximately 193 nm.

7. The method of claim 2 wherein exposing the photosensitive material to a source of radiation includes exposing the photosensitive material to radiation having a wavelength of approximately 248 nm.

8. The method of claim 2 wherein exposing the photosensitive material to a source of radiation includes exposing the photosensitive material to radiation having a wavelength of approximately 365 nm.

9. A method of fabricating a device using a photolithographic process, wherein a wavelength of light is used during the photolithographic process, the method comprising:

forming a first anti-reflective coating over a substrate;

providing a layer which is transparent to the wavelength of light over the first anti-reflective coating;

forming a second anti-reflective coating over the layer which is transparent to the wavelength of light;

providing a photosensitive material over the second anti-reflective coating; and

exposing the photosensitive material to a source of radiation including the wavelength of light.

10. The method of claim 9 wherein providing a first anti-reflective coating includes providing an anti-reflective layer with a complex refractive index which increases absorption of light passing through an interface of the transparent layer and the first anti-reflective coating.

11. The method of claim 10 wherein providing a second anti-reflective coating includes providing an anti-reflective layer with a complex refractive index which reduces reflectivity of light at an interface between the photosensitive material and the second anti-reflective coating.

12. The method of claim 11 wherein exposing the photosensitive material to a source of radiation includes selectively exposing portions of the photosensitive material to the radiation, the method further including:

developing the photosensitive material after exposure to the source of radiation; and

transferring a pattern defined by the remaining photosensitive material to at least one underlying layer.

13. A semiconductor device comprising:

a layer that is transparent to light having a wavelength of approximately 248 nm;

a first anti-reflective coating extending substantially entirely beneath the transparent layer.

14. The semiconductor device of claim 13 wherein the first anti-reflective coating has a complex refractive index with an imaginary part whose value is at least one.

15. The semiconductor device of claim 13 wherein the transparent layer includes a material selected from the group consisting of BPSG, PSG and TEOS.

16. The semiconductor device of claim 13 wherein the transparent layer includes an oxide.

17. The semiconductor device of claim 13 wherein the first anti-reflective coating includes a material comprising an organic polymer.

18. The semiconductor device of claim 13 wherein the first anti-reflective coating includes a material comprising silicon and nitrogen.

19. The semiconductor device of claim 13 wherein the first anti-reflective coating includes a material comprising silicon and oxygen.

20. The semiconductor device of claim 13 further including:

a second anti-reflective coating extending over the transparent layer.

21. A semiconductor device comprising:

a layer that is transparent to light having a wavelength of approximately 365 nm;

a first anti-reflective coating extending substantially entirely beneath the transparent layer.

22. The semiconductor device of claim 21 wherein the first anti-reflective coating has a complex

refractive index with an imaginary part whose value is at least one.

23. The semiconductor device of claim 21 wherein the transparent layer includes a material selected from the group consisting of BPSG, PSG and TEOS.

24. The semiconductor device of claim 21 wherein the transparent layer includes an oxide.

25. The semiconductor device of claim 21 wherein the first anti-reflective coating includes a material comprising silicon and nitrogen.

26. The semiconductor device of claim 21 wherein the first anti-reflective coating includes a material comprising silicon and oxygen.

27. The semiconductor device of claim 21 further including:

a second anti-reflective coating extending over the transparent layer.

28. A semiconductor device comprising:

a layer that is transparent to light having a wavelength of approximately 193 nm;

a first anti-reflective coating extending substantially entirely beneath the transparent layer.

29. The semiconductor device of claim 28 wherein the first anti-reflective coating has a complex refractive index with an imaginary part whose value is at least one.

30. The semiconductor device of claim 28 wherein the transparent layer includes a material selected from the group consisting of BPSG, PSG and TEOS.

31. The semiconductor device of claim 28 wherein the transparent layer includes an oxide.

32. The semiconductor device of claim 28 wherein the first anti-reflective coating includes a material comprising silicon and nitrogen.

33. The semiconductor device of claim 28 wherein the first anti-reflective coating includes a material comprising silicon and oxygen.

34. The semiconductor device of claim 28 further including:

a second anti-reflective coating extending over the transparent layer.

Abstract

Techniques are disclosed for fabricating a device using a photolithographic process. The method includes providing a first anti-reflective coating over a surface of a substrate. A layer which is transparent to a wavelength of light used during the photolithographic process is provided over the first anti-reflective coating, and a photosensitive material is provided above the transparent layer. The photosensitive material is exposed to a source of radiation including the wavelength of light. Preferably, the first anti-reflective coating extends beneath substantially the entire transparent layer. The complex refractive index of the first anti-reflective coating can be selected to maximize the absorption at the first anti-reflective coating to reduce notching of the photosensitive material.

39140.N11

Current List of Claims

1. (Previously amended) A method of fabricating a device using a photolithographic process, wherein a wavelength of light is used during the photolithographic process, the method comprising:

providing a silicon oxide layer over a surface of a substrate;

providing a continuous anti-reflective coating of a first thickness over the silicon oxide layer, wherein the anti-reflective coating is formed of a material selected from the group consisting of silicon oxides, silicon nitrides and silicon oxy-nitrides;

providing a layer which is transparent to the wavelength of light over the continuous anti-reflective coating and to a second thickness greater than the first thickness and as great as 20,000 Angstroms, wherein the transparent layer includes a material selected from the group consisting of BPSG, PSG and TEOS;

providing a photosensitive material above the layer that is transparent to the wavelength of light; and

exposing die photosensitive material to a source of radiation including the wavelength of light.

2. (Original) The method of claim 1 wherein the anti-reflective coating extends beneath substantially the entire transparent layer.

3. (Original) The method of claim 2 wherein providing an anti-reflective coating includes providing an anti-reflective coating with a complex refractive index which increases absorption of light passing through an interface of the transparent layer and the anti-reflective coating.

4. (Original) The method of claim 2 wherein exposing the photosensitive material to a source of radiation includes selectively exposing portions of the photosensitive material to the radiation.

5. (Original) The method of claim 4 further including:

developing the photosensitive material after exposure to the source of radiation; and transferring a pattern defined by the remaining photosensitive material to at least one underlying layer.

6. (Original) The method of claim 2 wherein exposing the photosensitive material to a source of radiation includes exposing the photosensitive material to radiation having a wavelength of approximately 193 nm.

7. (Original) The method of claim 2 wherein exposing the photosensitive material to a source of radiation includes exposing the photosensitive material to radiation having a wavelength of approximately 248 nm.

8. (Original) The method of claim 2 wherein exposing the photosensitive material to a source of radiation includes exposing the photosensitive material to radiation having a wavelength of approximately 365 nm.

9. (Currently amended) A method of fabricating a device using a photolithographic process, wherein a wavelength of light is used during the photolithographic process, the method comprising:

providing a continuous silicon oxide layer over a surface of a substrate;

forming a first anti-reflective coating over and in contact with the continuous silicon oxide layer, wherein the first anti-reflective coating forms a continuous first anti-reflective coating region, and wherein the first anti-reflective coating is formed of a material selected from the group consisting of silicon oxides, silicon nitrides and silicon oxy-nitrides;

providing a layer which is transparent to the wavelength of light over the first anti-reflective coating, wherein the transparent layer includes a material selected from the group consisting of BPSG, PSG and TEOS;

forming a second anti-reflective coating over the layer which is transparent to the wavelength of light, wherein the second anti-reflective coating forms a continuous second anti-reflective coating region, and wherein the second anti-reflective coating is formed of a material selected from the group consisting of silicon oxides, silicon nitrides and silicon oxy-nitrides;

providing a photosensitive material over the second anti-reflective coating; and

selectively exposing the photosensitive material located over the continuous first anti-reflective coating region and the continuous second anti-reflective coating region to a source of radiation including the wavelength of light;

developing the photosensitive material after exposure to the source of radiation; and

transferring a pattern defined by the remaining photosensitive material to at least one underlying layer.

10. (Original) The method of claim 9 wherein providing a first anti-reflective coating includes providing an anti-reflective layer with a complex refractive index which increases absorption of light passing through an interface of the transparent layer and the first anti-reflective coating.

11. (Original) The method of claim 10 wherein providing a second anti-reflective coating includes providing an anti-reflective layer with a complex refractive index which reduces reflectivity of light at an interface between the photosensitive material and the second anti-reflective coating.

12. (Original) The method of claim 11 wherein exposing the photosensitive material to a source of radiation includes selectively exposing portions of the photosensitive material to the radiation, the method further including:

developing the photosensitive material after exposure to the source of radiation; and

transferring a pattern defined by the remaining photosensitive material to at least one underlying layer.

Claims 13-34 (Withdrawn).

Claim 35 (Cancelled).

36. (Previously added) The method of claim 1 wherein the transparent layer includes an oxide.

Claims 37-40 (Cancelled).

41. (Previously added) The method of claim 9 wherein the transparent layer includes an oxide.

Claim 42 (Cancelled).

43. (Previously added) The method of claim 9 wherein the first anti-reflective coating includes a material comprising silicon and nitrogen.

44. (Previously added) The method of claim 9 wherein the first anti-reflective coating includes a material comprising silicon and nitrogen.

Claim 45 (Cancelled).

46. (Previously added) The method of claim 9 wherein the second anti-reflective coating includes a material comprising silicon and nitrogen.

47. (Previously added) The method of claim 9 wherein the second anti-reflective coating includes a material comprising silicon and oxygen.

Claims 48-49 (Cancelled).